Electro-Technology

ANNOTATED
EDITORIAL INDEX

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Contents

Subject Index 2
- Science and Engineering 2
- Components, Electrical/Electronic 3
- Components, Mechanical/Structural 5
- Computing Machines 6
- Design Considerations 6
- Heat Flow 7
- Instruments and Test Equipment 7
- Materials, Electrical/Electronic 7
- Materials, Mechanical/Structural 9
- Motors 9
- Production and Assembly Techniques 9
- Systems 10
- Test and Measurement 12
- Research Notes 13
- Editorials 14
- Design Trends 14

Authors' Index 15

Alphabetical Subject Cross Index 18

Editorial Subject Classification 20

New Alphabetical Subject Cross Index 21

New Editorial Subject Classification 23

Subject Classification | Month | Page

SCIENCE AND ENGINEERING

Fundamentals of Measurement, A. G. McNish ..... May 113

The historical development of measurement systems and standards is examined, beginning with an elucidation of the conceptual basis of measurement. Techniques of measurement, including aspects of precision and accuracy, are described. The basic quantities of mass, time and temperature are examined, as are the other physical quantities, including the electrical. The impact of contemporary technology on measurement concepts and techniques is discussed. The use of wavelengths of given elements for standards is an example.

Chemistry of Materials

The Materials of Thin-Film Devices—Substrates/Conductive Films/Restrictive Films—S. A. Halaby; Dielectric Films/Semiconducting Films/Superconducting Films—L. V. Gregor; Ferromagnetic Films—S. M. Rubens ..... Sep 95

The systems performance of a given thin-film device depends on the complex interactions of the particular materials which the requirements of the device may dictate. The fundamental nature of these materials, the parameters of their behavior and the influence of processing techniques on their properties are examined in this report.

Dielectrics

Dielectrics in 1962: Phenomena, Materials, Devices. A. E. Javitz, Senior Editor ..... Jan 91

Current research in the field of dielectrics is examined from three interrelated viewpoints: phenomena, materials and devices. Various mechanisms of breakdown are analyzed for gases, liquids and solids. New polymeric insulating materials are reported and test data given. Special problems such as the effect of cryogenic environment are discussed. In devices, new thin-film techniques are described, as are specially formulated microwave dielectrics. Advances in test methods are reviewed.

Mathematics

Solution of Quadratic, Cubic and Quartic Equations, F. B. Anderson ..... Jan 53

Methods are depicted for so altering the conventional forms of solution for quadratic, cubic and quartic equations as to permit readier exact, approximate and graphical solutions. Circuit- and system-analysis applications of the methods, and their limitations, are discussed.

Root-Locus Systems Analysis, A. W. Langill, Jr. ... Oct 79

Basic root-locus methods are discussed and described. The use of the Spirule graphical device is stressed. Examples are given of applications to the design of an autopilot control and a lead-lag compensation network and to polynomial factoring and network transfer-admittance calculations.

Matrix Computation Methods, P. C. Constant, Jr. . Nov 68

Methods are described for efficient solution of linear equations with constant coefficients and for matrix inversion. Elimination and rotation systems suitable for digital computer calculations are presented and discussed.

Sequential Switching Logic, M. D. Wilt ..... Dec 50

Design of sequential switching circuits using flip-flops and diode gates is discussed. A new technique for minimizing components is presented along with standard factoring methods using Karnaugh maps and Boolean minimization.

Digital-Computer Iterative Methods, R. Townsend Dec 102

Using the digital computer as a mathematical tool is the best way to grasp its principles and potential power. This article poses a common calculation—that of finding the square root—as a problem for digital computation. A simple hypothetical computer is programmed to perform the sample calculation in a manner which requires no previous knowledge of computer operation.

Network Analysis

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Methods are depicted for so altering the conventional forms of solution for quadratic, cubic and quartic equations as to permit readier exact, approximate and graphical solutions. Circuit- and system-analysis applications of the methods, and their limitations, are discussed.

Graphical Analysis of Transfer Functions, P. R. Amlinger ..... Jan 71

Transfer functions of many filter networks (high-pass, low-pass, band-pass, band-elimination) can be reduced to two simple, symmetrical functions whose vector diagrams in the complex plane are circles (or semicircles). The vector diagrams, developed on the principles of conformal mapping, are then used to determine various circuit characteristics.

Application of Matrix Algebra to Circuit Design, L. E. Getgen ..... Feb 70

The analysis of four-pole networks by the use of matrix-algebra network parameters, interconnection of four-pole networks, and transformation of parameters are discussed. The matrix method of transistor-circuit design is presented.

Network Analysis by Kreer Delta-*T* Transformation, F. B. Anderson ..... Jul 62

The Kreer delta-*T* transformation is an ingenious means of analyzing and designing envelope-shaping and frequency-suppression networks and of deriving the properties of the two-winding hybrid transformer.

Subject Classification	Month	Page
Transistor Transformation Matrix, H. E. Stockman. A complete third-order matrix table provides a self-contained transformation procedure for transistor parameters. Cascaded stages may be analyzed by adding these matrices.	Sep	46
High-Frequency Amplifier Design Using Admittance Parameters: Part 1—Basic Concepts, G. Johnson, P. Norris and F. Opp. Advantages of using y parameters to characterize high-frequency transistors are detailed. Expressions for various forms of power gain and the Linvill and Stern stability factors are developed in terms of y parameters. An understanding of these expressions is basic to the design of high-frequency amplifiers.	Nov	74
The Exponential RC Filter, M. J. Hellstrom. A graphical method for analysis of poles and zeros of the network parameters of the exponential lumped-RC ladder is presented. In addition, the network parameters for the exponential distributed-RC network are derived by increasing the number of stages in the lumped-RC ladder without bound while the values of the network elements approach zero.	Dec	62
High-Frequency Amplifier Design Using Admittance Parameters: Part 2—Techniques, G. Johnson, P. Norris and F. Opp. Basic gain and stability relationships developed in Part 1 of this series are applied. The Linvill chart is developed from a graphical representation of power flow through a linear active network. The principles are illustrated by design calculations for an amplifier stage using y parameters and the Linvill chart.	Dec	66

Network Synthesis

Design of a Pulse-Narrowing Network, H. M. Sierra. This article describes a network design by synthesis methods. The resultant network is capable of doubling magnetic-tape recording density.	Sep	38

Physics

Thermodynamics of Compressible Fluids, R. P. Benedict and W. G. Steltz. The laws of fluid mechanics are inadequate for flow analysis when the simplifying assumption of incompressibility is invalid, as with gases. Thermodynamic principles are applied to develop equations for a generalized flow process, leading to a compressible-flow table. Practical problems illustrate the methods of analysis.	Feb	85
Lasers: Principles and Uses, S. A. Collins, Jr. The laser is the equivalent of the r-f or microwave oscillator. Light applied to a Fabry-Perot cavity results in selective oscillations that produce a coherent light output in a well-collimated beam. The principles of operation, significant features and uses of lasers are described.	Mar	64
Nonlinear Magnetics, R. C. Barker. Starting with a discussion of the various types of magnetic materials that are available, the author describes the properties of these materials which make them useful in designing devices. Basic principles which are used repeatedly in designing and analyzing nonlinear magnetic circuits are presented, followed by notes on application of magnetic devices in logic, amplification, etc.	Mar	95
Thermodynamics of Constant-Density Fluids, W. G. Steltz, and R. P. Benedict. The application of thermodynamic principles to the analysis of the flow of real fluids was demonstrated for compressible fluids in our February 1963 Science & Engineering feature. The methods are now projected further to apply to constant-density fluids such as oil and water. Numerical examples are included.	Apr	70
Principles of Optics, T. C. Hutchison. With certain precautions, visible-light optical principles can be applied to broader sectors of the electromagnetic spectrum. Fundamental physical laws of optics are presented, both for this purpose and for the understanding and analysis of the rapidly diversifying applications of visible light in control, computer, communication and measurement systems.	Jun	83
Temperature and Its Measurement, R. P. Benedict. The true nature and difficulties of defining absolute temperature references are discussed. The relations between temperature references based on arbitrary properties of materials and those derived from thermodynamic processes are established. Included are comparisons of important temperature-measuring techniques employing resistance changes, bridges and thermocouples.	Jul	71
Vibration Control, J. E. Ruzicka. Electronic and other sensitive precision equipment is exposed to numerous environmental hazards, especially in aerospace applications. Vibration is one of the most devastating, leading to both catastrophic and fatigue failure. The basic physics of vibration and its transmission provides the foundation for studying the various techniques of vibration control which have been found effective.	Aug	63
Temperature Measurement in Moving Fluids, R. P. Benedict. Thermodynamic states encountered in moving fluids are considered in order to evaluate the validity of temperature measurements in such fluids. Idealized and real moving fluids and temperature probes are investigated, and correction factors are derived for making measurements under various conditions.	Sep	56
The Materials of Thin-Film Devices—Substrates/Conductive Films/Restrictive Films—S. A. Halaby: Dielectric Films/Semiconducting Films/Superconducting Films—L. V. Gregor; Ferromagnetic Films—S. M. Rubens. The systems performance of a given thin-film device depends on the complex interactions of the particular materials which the requirements of the device may dictate. The fundamental nature of these materials, the parameters of their behavior and the influence of processing techniques on their properties are examined in this report.	Sep	95
Electric and Magnetic Fields, A. Glaser. The study of electric and magnetic fields provides the classical basis for the art of electrical engineering. The basic equations and relations between variables in all types of electromagnetic fields are given and discussed in relation to their importance in designing electrical and electronic equipment.	Nov	81
Analog Simulation, R. P. Benedict. The basic principles used in the application of analogous relationships are described and proof of their mathematical similarities is given. Two examples are considered: fluid systems in terms of analogous electrical systems; and gas systems in terms of the analogous water systems.	Dec	73

COMPONENTS, ELECTRICAL/ELECTRONIC

Pulsed Nuclear Radiation Effects on Electronic Components and Materials, W. Schlosser, C. P. Lascaro and J. Key. The effects of pulsed nuclear radiation on coaxial cables, resistors and ferrite inductors have been studied. Such effects are distinct from those experienced in steady-state radiation and would be particularly critical in electronic equipment and systems operating in combat nuclear environment. The effects on cables are particularly important since they tend to influence the accuracy of test instrumentation in which cables are used.	May	106

Batteries

Survey of Electrochemical Batteries, N. D. Wheeler. This article presents a survey of data on presently available electrochemical cells. It is intended to aid the reader in selecting an optimum energy source for any device that requires battery power.	Jun	68

Subject Classification | Month | Page

Contact Devices

A Second Evaluation of The Industrial "300-Volt" Relay, W. Ketterer and W. Frank ..... Mar 171
Results of electrical and mechanical life tests are reported on three types of compact machine-tool relays with contacts evaluated in four operational modes: make contact, break contact, seal in and interlock other circuits. With continuing improvements in design, acceptable reliability for industrial service is predicted.

New Relay Developments. H. Falk ..... Jul 143
Industry-wide standards for high-reliability relays and several new devices were discussed at the National Conference on Electromagnetic Relays.

Electron Tubes

Counter-Tube Drive Circuits, A. J. Schultz..... Aug 90
The glow-transfer counter tube has the unique characteristic of counting and displaying simultaneously with a relative minimum of circuit elements. In addition to counting, the tube is capable of subtracting, frequency-dividing, keying, timing, and various other functions.

Magnetic Amplifiers

A Shunt-Loaded Magnetic Amplifier, E. W. Manteuffel and T. A. Phillips ..... Apr 112
The output voltage of a new type of magnetic amplifier is controllable in amplitude rather than variation of pulse width. Theory of operation is derived and various circuits are discussed. Experimental results are presented.

Magnetic Components

Specification and Testing of Shielded Transformers, B. I. Sommer and G. W. Plice ..... May 102
Optimization of transformer performance for applications involving low-level signals is discussed. The most important test techniques are described and specification is related to materials and cost considerations.

The Nature of Ferroresonance, T. Kavounas ..... Aug 49
Many power supplies utilize the phenomenon of ferroresonance for their primary means of regulation against line-voltage changes. Flux density, magnetic potential, and voltage relationships determine the operation of ferroresonant transformers.

Magnetic Recording Systems

High-Stability Magnetic Tape for Data-Processing Systems, A. Rusch, C. P. Lascaro and E. Beekman ..... Dec 91
The reliability of the magnetic-recording-tape subsystem has an important effect on the effective operation of high-speed information-sensing and data-processing systems, particularly under service environments. This report summarizes the results of a research project at USAELRDL which has resulted in a commercially feasible tape apparently free of defects encountered in conventional tapes.

Microcircuit Assemblies

Microelectronic Components: Capability and Availability, Staff Report ..... Oct 103
A survey of presently available microelectronic devices. Representative approaches to microelectronics are illustrated, and manufacturers' data on modules, thin-film circuits and semiconductor integrated circuits are tabulated.

Microwave Components

Magnetic Shielding Practice in Electronic Packaging, D. E. Longmire..... Jan 63
Unwanted magnetic fields can affect the performance of almost any device having a magnetic structure, such as a transformer or relay, or (additionally) involving electron beams, such as microwave devices. Some general principles for shielding against magnetic influences are presented and several examples of successes and failures in packaging microwave devices under severe environmental conditions are cited.

Magnetic Materials for Millimeter Wave Devices, G. P. Rodrigue ..... Sep 78
Four classes of materials are examined for their capabilities in the design of millimeter and submillimeter wave devices: 1) conventional polycrystalline ferrites, 2) single-crystal yttrium iron garnet, 3) hexagonal-crystal ferrites, and 4) the antiferromagnetic compounds. Applications include resonant and nonresonant devices.

Microwave Devices

Electromagnetic Delay Lines, Staff Report ..... Jan 143
A description of the various terms that are used to define delay-line operation and characteristics, what these terms mean to the user, and how the two principal types of delay line (distributed- and lumped-constant) are constructed.

Power Supplies

Feedback Techniques for Transistor Voltage Regulation, B. D. Jimerson ..... Mar 76
The use of transistor feedback circuits to regulate voltage sources is analyzed in this article. A general regulation equation is developed and applied to a typical regulation network. Design considerations in feedback stability and the use of Zener-diode reference sources are discussed.

The Switching Mode in D-C Voltage Regulation, A. Lambert..... Jun 78
The modulation of power in switching-type d-c voltage regulators is discussed. Several switching-type systems are presented. The concepts involved apply equally well to continuous modulation of power in equipment such as servo systems and adjustable-speed drives.

Semiconductor Devices

Semiconductor Rectifier Diodes and Controlled Rectifiers, E. J. Diebold and D. W. Borst ..... Feb 106
A survey of current and future trends in the design and application of diodes and controlled rectifiers for high-power applications. It is shown that silicon is the principal material now being used and that, although alloying and diffusing techniques are now more important, epitaxial growth holds great promise for the future.

Voltage-Driven Hall Generators, D. Silverman ..... Jun 113
With thin-film Hall generators, voltage drive is feasible. Use of voltage drive, rather than current drive, has several advantages: fluctuations in external resistance have only a minor effect; high-impedance signal sources can be used; sensitivity is increased; and temperature variations have less effect on output. A simple method of obtaining additional temperature compensation is also discussed.

Reliability of the Field-Effect Transistor, P. Holden Jul 58
The FET has high intrinsic reliability. Theory indicates that it may be more resistant to catastrophic failure than ordinary transistors, but susceptible to additional degradation mechanisms. This article analyzes failure mechanisms, and presents storage and operating life test data for germanium and silicon devices.

Transistor Transformation Matrix, H. E. Stockman..... Sep 46
A complete third-order matrix table provides a self-contained transformation procedure for transistor parameters. Cascaded stages may be analyzed by adding these matrices.

Applications of Varactor Diodes, R. L. Ernst and J. K. Fitzpatrick ..... Sep 54
Theory of the semiconductor voltage-variable capacitor is briefly presented. Commonly used

varactor parameters and their significance are described. Several representative applications—frequency multipliers, frequency converters, parametric amplifiers—are discussed, and use of the Manley-Rowe power equations is illustrated.

Semiconductor Materials for High Temperatures, E. G. Bylander ..... Sep 123
What are the prospects of eventually obtaining a high-temperature transistor? This article analyzes the problems and gives some of the answers. The basic limitations on device performance are reviewed, and criteria for high-temperature semiconductor materials are developed. Processing problems are discussed, and after considering cost and reliability, the outlook for availability of devices is presented.

Turn-Off Silicon Controlled Rectifiers, H. F. Storm . Oct 62
The operation of turn-off SCR's is discussed. Consideration is given to turn-off current gain, speed, problems with larger currents, and applications. A circuit model with an equivalent-current bypass is used to illustrate the turn-off mechanism.

Microelectronic Components: Capability and Availability, Staff Report ..... Oct 103
A survey of presently available microelectronic devices. Representative approaches to microelectronics are illustrated, and manufacturers' data on modules, thin-film circuits and semiconductor integrated circuits are tabulated.

Protecting Silicon Rectifiers from Transient Overloads, K. Sueker ..... Nov 105
Transient overloads may seriously affect the reliability of silicon power rectifiers. Such overloads may arise from switching, commutation, dynamic loads, and other sources. Simple methods of protecting rectifiers from such transients are presented. Susceptibility of SCR's and controlled-avalanche rectifiers are also discussed.

Switches

Reed Logic, L. A. Burnett..... Mar 120
The reed switch device has reliability competitive with semiconductor devices and may be used to construct relay-type logic circuits. This article examines reed switch reliability and discusses a number of reed logic configurations.

Thermoelectric Devices

Dynamic Behavior of a Thermoelectric Heat Pump, R. Zito, Jr. ..... Feb 64
The fundamental aspects of thermoelectric phenomena are outlined and their significance with regard to the operation of a heat pump (refrigerator) is given in detail. An outline of the basic design parameters for such a system is presented.

Graphical Methods of Solving Thermoelectric-Heat-Pump Problems, P. C. Watson..... Jun 74
A test procedure is outlined for producing characteristic data of heat-pump modules as the basis of working charts for cooling-systems design. Six examples and their solutions are presented.

Transducers

Survey of Pressure Transducers—Principles and Design, K. S. Lion ..... Jan 50
A presentation of available transducer systems for measurement of pressure, particularly in turbulent-flow fields. Principles and engineering parameters in general transducer design are studied. Workable systems for measurement of static and dynamic pressures are analyzed.

The Toroidal Displacement Transducer, R. K. Brodersen ..... Mar 115
The better known electrical displacement transducers are reviewed, and the requirements for displacement transducers in precision instruments are discussed. A new toroidally wound electrodynamic displacement transducer is described.

The A-C Tachometer, J. Frey..... Aug 88
Alternating-current tachometer generators include damping tachometers, rate generators and integrators. The characteristics of these types depend upon basic operating and structural principles.

Infrared Detectors, F. Schwarz ..... Nov 116
Infrared detection devices including photoconductive, photoemissive and thermal devices are discussed. Emphasis is placed upon thermal detectors—semiconductor or thermistor bolometers, metal bolometers and radiation thermocouples and thermopiles.

Wire and Cable

Problems in Insulated Wire and Cable in Space-Vehicle Systems, H. S. Adams..... Sep 133
Informed and careful choice of space-system wire and cable is essential for reliability. The selection problem is clarified by distinguishing functional from environmental requirements of wire. Guidance is given for intelligent evaluation of the two primary elements of wire and cable: the conducting and the insulating materials.

Advanced Magnet-Wire Systems, W. W. Pendleton Oct 95
The limiting factor in many complex devices is the inability of conventional magnet-wire systems to function under very high temperatures (up to the 650–1000 C region) and in other severe environments. This article summarizes work done in developing special conductor metals and new inorganic insulations able to meet these conditions. Associated materials are also discussed.

COMPONENTS, MECHANICAL/STRUCTURAL

Bearings

Ball Bearings Designed to Meet Special Application Requirements—1, Frank J. Oliver..... Feb 56
Part 1 of series deals with the development of miniature and instrument precision ball bearings, and the instruments available to evaluate their performance in terms of starting and running torque, vibration and noise. Gyro bearings are discussed, as well as smooth-running and quiet bearings of larger size for motors, spindles and appliances.

Ball Bearings Designed to Meet Special Application Requirements—2, F. J. Oliver..... Mar 80
Above 400 F where even stabilized 52100 steel begins to soften, a wide variety of bearing materials is being evaluated in the laboratory and used on special orders or experimentally. Test results are summarized for stainless steels, tool steels, high Ni, Co and W alloys, cermets and ceramics (now being considered for bearing parts at temperatures approaching 2500 F).

Ball Bearings Designed to Meet Special Application Requirements—3, F. J. Oliver..... Apr 102
Concluding part of series deals with evaluation of self-lubricating ball separator materials for bearings intended to operate submerged in liquified gases (H_2, O_2, N_2). Experimental work on lubrication of bearings in the hard vacuum of space is reported, and continuing studies are outlined. AISI 440 C stainless steel is found to be a common choice for rings and balls in both environments.

Shock and Vibration Isolators

Rigid-Foam Structures for Shock Protection of Electronic Subassemblies, B. H. Anderson ..... Sep 90
Properties of rigid-urethane support structures, machined or molded to the contours of the individual electronic components, are assesed in terms of mechanical-energy absorption, strength-to-weight ratios, dielectric properties, humidity and temperature effects, design flexibility and manufacturing costs.

Subject Classification	Month	Page

Thermal

Design of Bimetal Actuators *for snap-action and constant-friction devices,* C. F. Alban and C. C. Perry ..... Apr 75

Conventional design relationships for the design of bimetal actuators are inadequate when the operated device exhibits mechanical hysteresis, as with snap action or uniform friction. For these cases, expressions are developed to provide for the additional factors involved, and their use in design described.

COMPUTING MACHINES

Applications

Multivariant Function Generation, A. W. Langill, Jr. ..... Jun 52

One of the most important applications of analog computations is in the simulation of nonlinear control systems. In many practical systems, however, an element is present which can be characterized only in terms of multivariant functions. Simulation techniques, including tapped potentiometers and diode generators, for such cases are described.

The Computer as a Design Tool; 1. Transistor Switching Circuit Design, 2. Design of Electrical Machinery, H. Falk, P. H. Conceicao and K. C. Parton ..... Jul 48

Problems and prospects of computer-aided design are discussed in a symposium on transistor switching circuits and in a description of some experiences in computer design of electrical machinery.

Matrix Computation Methods, P. C. Constant, Jr. . Nov 68

Methods are described for efficient solution of linear equations with constant coefficients and for matrix inversion. Elimination and rotation systems suitable for digital computer calculations are presented and discussed.

Digital-Computer Iterative Methods, R. Townsend. Dec 102

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DESIGN CONSIDERATIONS

Environmental Effects

Vibration Control, J. E. Ruzicka ..... Aug 63

Electronic and other sensitive precision equipment is exposed to numerous environmental hazards, especially in aerospace applications. Vibration is one of the most devastating, leading to both catastrophic and fatigue failure. The basic physics of vibration and its transmission provides the foundation for studying the various techniques of vibration control which have been found effective.

Magnetic Shielding Practice in Electronic Packaging, D. E. Longmire ..... Jan 63

Unwanted magnetic fields can affect the performance of almost any device having a magnetic structure, such as a transformer or relay, or (additionally) involving electron beams, such as microwave devices. Some general principles for shielding against magnetic influences are presented and several examples of successes and failures in packaging microwave devices under severe environmental conditions are cited.

Pulsed Nuclear Radiation Effects on Electronic Components and Materials, W. Schlosser, C. P. Lascaro and J. Key ..... May 106

The effects of pulsed nuclear radiation on coaxial cables, resistors and ferrite inductors have been studied. Such effects are distinct from those experienced in steady-state radiation and would be particularly critical in electronic equipment and systems operating in combat nuclear environment. The effects on cables are particularly important since they tend to influence the accuracy of test instrumentation in which cables are used.

Design Criteria for Solders in Cryogenic Environments, J. L. Christian ..... Jun 109

An increasing number of applications require the use of soldered joints in aerospace-vehicle electrical/electronic systems operating in cryogenic environments. This article reports on an investigation of the mechanical properties of thirteen different solders from 78 to −423 F, tabulates the results, and interprets their design significance.

Electrical Insulation at Cryogenic Temperatures, K. N. Mathes ..... Sep 72

The properties of electrical insulating materials may be quite different at cryogenic temperatures. A serious problem thus exists in designing electrical devices, equipment and systems for reliable performance in cryogenic environments. Mechanical and dielectric properties of insulating materials at those temperatures obtained in a NASA-sponsored investigation are presented here and their design significance is analyzed. Electrical-breakdown data on the cryogenic liquids is also given.

The Nature of Materials Failure Under Space Conditions, Staff Report ..... Sep 128

Many aspects of space environments are more subtle than the much-discussed high-energy radiation. Some of these are similar to "normal-condition" hazards, but differ in severity. Certain test techniques not commonly known must be used for significant study of these space effects on materials.

Human Factors

Color-Coded Displays for Data-Processing Systems, S. L. Smith ..... Apr 63

Color-coded displays have been investigated to determine their usefulness in man-machine information transfer functions. The results of these experimental studies confirm the potential value of such display designs. Specific data are presented and analyzed.

Man-Computer Information Transfer, S. L. Smith.. Aug 83

An examination of the engineering and psychological problems that must be solved to establish effective means of information transfer between men and computers in data-processing systems. Solutions to such problems are proposed within the context of systems-engineering conceptual requirements and possible limitations.

Magnetic Interference

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Radio Noise and Interference

Radio Interference from Carbon-Brush Operation, R. E. Nelson and J. E. Diehl ..... Jul 53

The physical phenomena underlying radio interference from rotating electrical machines are classified for discussion. Results of extensive

laboratory tests made to explore the relative importance of the complex causative factors illustrate the reasoning.

Reliability

Elements of a Practical Reliability-Engineering Program, E. L. Royal ..... Jan 59
Reliability engineering is not design engineering, but is definitely a design determinant. Primary reliability concepts and terms such as *failure rate* and *confidence level* are explained for the design engineer.

Statistical Circuit Analysis Based on Part Test Data, F. A. Applegate ..... May 140
The reliability of a circuit is no better than that of its component parts. An accurate and efficient part testing program is described and its results are then applied to the statistical analysis of the worst-case circuit design in which the parts are to be used.

Reliability of the Field-Effect Transistor, P. Holden ..... Jul 58
The FET has high intrinsic reliability. Theory indicates that it may be more resistant to catastrophic failure than ordinary transistors, but susceptible to additional degradation mechanisms. This article analyzes failure mechanisms, and presents storage and operating life test data for germanium and silicon devices.

"Stress Analysis" of Switching-Circuit Reliability, H. F. Najjar ..... July 68
Overall circuit and system reliability may be calculated from measured individual-component reliability by using a "stress" concept.

Use of Failure Statistics in Design, W. B. Bishop ... Jul 97
By specifying probability of failure of a part during the wear-out-failure period, the designer may be able to make equipment both more reliable and more economical. The author advocates use of the failure-module concept of periodic replacement, based on specification of wearout failure. A generalized expression of the probability-density function of parts is developed.

Pessimistic Circuit Design, N. A. Fruci ..... Oct 74
A simple transistor gate circuit is used to demonstrate the pessimistic method of switching-circuit design. The resultant design is evaluated by statistical means. Distribution and variability of the basic components in the circuit are discussed and usable component parameter distributions are presented.

Protecting Silicon Rectifiers from Transient Overloads, K. Sueker ..... Nov 105
Transient overloads may seriously affect the reliability of silicon power rectifiers. Such overloads may arise from switching, commutation, dynamic loads, and other sources. Simple methods of protecting rectifiers from such transients are presented. Susceptibility of SCR's and controlled-avalanche rectifiers are also discussed.

Thermal Design Factors

Dynamic Behavior of a Thermoelectric Heat Pump, R. Zito, Jr. ..... Feb 64
The fundamental aspects of thermoelectric phenomena are outlined and their significance with regard to the operation of a heat pump (refrigerator) is given in detail. An outline of the basic design parameters for such a system is presented.

Choice of Fluids for Cooling Electronic Equipment, A. F. Knights ..... Jun 57
A systematic procedure for selecting the best fluid for a given application is presented. Fourteen fluid properties and their effects on cooling-system design are discussed. Two useful indices for comparison of different fluids are developed: the heat-transfer/pumping-power index (γ) and the ducting-weight index (ϕ). Over a range of temperatures, values of these indices, relative to air, are given for eight liquids and eight gases.

HEAT FLOW

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A test procedure is outlined for producing characteristic data of heat-pump modules as the basis of working charts for cooling-systems design. Six examples and their solutions are presented.

INSTRUMENTS AND TEST EQUIPMENT

Design (for application, see Test and Measurement)

Radio-Frequency Voltage Measurement, B. P. Hand ..... Oct 109
Basic principles of devices, instruments and techniques are described, covering frequency range from 100 kc to 1 Gc. Principles of thermal converters—resistance elements, thermistors and barretters—and other transfer devices are discussed. Commercial types of r-f voltmeters are distinguished. Calibration techniques and highest accuracy standards are described in detail.

MATERIALS, ELECTRICAL/ELECTRONIC

Filament-Wound Reinforced Plastics for Electrical Equipment, Staff Report ..... Jan 67
A study of filament winding as a technique in the design of high-strength electrical components. The design properties of materials, primarily glass-fiber-reinforced epoxies, are reviewed and interpolated. Test methods for finished structures are described and evaluated.

Pulsed Nuclear Radiation Effects on Electronic Components and Materials, W. Schlosser, C. P. Lascaro and J. Key ..... May 106
The effects of pulsed nuclear radiation on coaxial cables, resistors and ferrite inductors have been studied. Such effects are distinct from those experienced in steady-state radiation and would be particularly critical in electronic equipment and systems operating in combat nuclear environment. The effects on cables are particularly important since they tend to influence the accuracy of test instrumentation in which cables are used.

Special Report—Electrical/Electronic Materials, A. E. Javitz ..... Sep 61
Nine articles providing an analysis of advanced materials problems in the total spectrum of electrical/electronic equipment and systems engineering, including components, devices and subsystems.

The Materials of Thin-Film Devices—Substrates/Conductive Films/Restrictive Films, S. A. Halaby; Dielectric Films/Semiconducting Films/Superconducting Films, L. V. Gregor; Ferromagnetic Films, S. M. Rubens ..... Sep 95
The systems performance of a given thin-film device depends on the complex interactions of the particular materials which the requirements of the device may dictate. The fundamental nature of these materials, the parameters of their behavior and the influence of processing techniques on their properties are examined in this report.

Subject Classification	Month	Page
Effects of Fabrication on Design Properties of Materials, B. Bennett ..... The environment of processing and fabrication may degrade materials (for example, thermoplastics) and thus affect the performance of finished parts. The design engineer therefore cannot safely apply handbook values without making adequate provisions for such possible property changes. Proper parts design and quality control are necessary to reduce degradation to the minimum.	Nov	108

Conductor Materials

High-Strength Copper-Base Alloys, C. L. Bulow .... New high-strength copper alloys are discussed and evaluated within the framework of electrical/electronic design. Consideration is given to mechanical, electrical, thermal and corrosion-resistance characteristics.	Feb	113
Problems in Insulated Wire and Cable in Space-Vehicle Systems, H. S. Adams ..... Informed and careful choice of space-system wire and cable is essential for reliability. The selection problem is clarified by distinguishing functional from environmental requirements of wire. Guidance is given for intelligent evaluation of the two primary elements of wire and cable: the conducting and the insulating materials.	Sep	133
Advanced Magnet-Wire Systems, W. W. Pendleton. The limiting factor in many complex devices is the inability of conventional magnet-wire systems to function under very high temperatures (up to the 650-1000 C region) and in other severe environments. This article summarizes work done in developing special conductor metals and new inorganic insulations able to meet these conditions. Associated materials are also discussed.	Oct	95

Contact Materials

Radio Interference From Carbon-Brush Operation, R. E. Nelson and J. E. Diehl ..... The physical phenomena underlying radio interference from rotating electrical machines are classified for discussion. Results of extensive laboratory tests made to explore the relative importance of the complex causative factors illustrate the reasoning.	Jul	53

Dielectrics

Choice of Fluids for Cooling Electronic Equipment, A. F. Knights ..... A systematic procedure for selecting the best fluid for a given application is presented. Fourteen fluid properties and their effects on cooling-system design are discussed. Two useful indices for comparison of different fluids are developed: the heat-transfer/pumping-power index (γ) and the ducting-weight index (ϕ). Over a range of temperatures, values of these indices, relative to air, are given for eight liquids and eight gases.	Jun	57

Electrical Insulation and Dielectrics

Dielectrics in 1962: Phenomena, Materials, Devices, A. E. Javitz ..... Current research in the field of dielectrics is examined from three interrelated viewpoints: phenomena, materials and devices. Various mechanisms of breakdown are analyzed for gases, liquids and solids. New polymeric insulating materials are reported and test data given. Special problems such as the effect of cryogenic environment are discussed. In devices, new thin-film techniques are described, as are specially formulated microwave dielectrics. Advances in test methods are reviewed.	Jan	91
Application Problems in Electrical Insulation—1, A. J. Warner ..... Current problems in the application of electrical insulation materials and systems to transformers and rotating-machinery design are examined in terms of a literature review. Significant work abroad as well as in this country is referenced and interpreted.	Feb	101
Application Problems in Electrical Insulation—2, A. J. Warner ..... The second article in a two-part series summarizes current design problems and research investigations in such areas as capacitors, thin-film devices, printed-circuit modules and telecommunication cables. Not only insulating materials but also the other elements of the materials systems are considered as part of a "unified" approach. A critical review of the current literature (both U.S.A. and overseas) is the basis of the article.	Mar	71
Electrical Insulation at Cryogenic Temperatures, K. N. Mathes ..... The properties of electrical insulating materials may be quite different at cryogenic temperatures. A serious problem thus exists in designing electrical devices, equipment and systems for reliable performance in cryogenic environments. Mechanical and dielectric properties of insulating materials at those temperatures obtained in a NASA-sponsored investigation are presented here and their design significance is analyzed. Electrical-breakdown data on the cryogenic liquids are also given.	Sep	72
Perspectives in Insulation—Application Trends and Problems, A. E. Javitz ..... The technical program of the Fifth National Electrical Insulation Conference (IEEE-NEMA) is selectively reviewed. The papers discussed deal with materials capabilities, application problems and test procedures, as well as with mechanisms of insulation failure and the fundamental behavior of insulating materials.	Sep	84
Problems in Insulated Wire and Cable in Space-Vehicle Systems, H. S. Adams ..... Informed and careful choice of space-system wire and cable is essential for reliability. The selection problem is clarified by distinguishing functional from environmental requirements of wire. Guidance is given for intelligent evaluation of the two primary elements of wire and cable: the conducting and the insulating materials.	Sep	133
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Magnetic Materials

Ceramic Permanent-Magnet Fields for Motors, J. R. Ireland ..... Permanent magnets have advantages over wound fields for motors, but a simple substitution is not practical. Guidance to selection and application of ceramic-magnet materials is presented, with descriptions of resulting motor properties.	Mar	86
Ferrites—Materials and Applications, H. Severin ... A basic review of the state of the art in ferrites for electronic applications. The magnetic, physical and electronic properties of materials are illustrated and evaluated. Frequency dependence, magnetic design parameters and remanence are investigated. Projections are made for future applications.	May	146
Applications Analysis of New R-F Ferrites, W. W. Malinofsky and M. Eisenberg ..... Advantageous properties of new "in-production," as well as experimental, ferrite materials are discussed in relation to diverse r-f applications in military communications devices and systems. Applications (prototype and production) include: chokes, filters, inductors, delay lines, antenna elements, and various types of transformers.	Jul	87

Magnetic Materials for Millimeter Wave Devices, G. P. Rodrigue ..... Sep 78
Four classes of materials are examined for their capabilities in the design of millimeter and submillimeter wave devices: 1) conventional polycrystalline ferrites, 2) single-crystal yttrium iron garnet, 3) hexagonal-crystal ferrites, and 4) the antiferromagnetic compounds. Applications include resonant and nonresonant devices.

Advanced Magnet-Wire Systems, W. W. Pendleton. Oct 95
The limiting factor in many complex devices is the inability of conventional magnet-wire systems to function under very high temperatures (up to the 650–1000 C region) and in other severe environments. This article summarizes work done in developing special conductor metals and new inorganic insulations able to meet these conditions. Associated materials are also discussed.

Metals

Bonding and Welding Techniques for Microcircuits, Staff Report ..... Mar 89
A study of feasible methods for making reliable interconnections in microelectronic packages. Three procedures (soldering, welding and heat-pressure bonding) are introduced and analyzed for effects on design specifications. A sample materials specification for welded interconnections is also presented.

Semiconductor Materials

Laser Materials and Devices—A Research Report, R. D. Haun ..... Sep 63
Criteria for useful laser materials are established in this report. The relative merits of the laser materials now being studied—crystal, glass, semiconductor, organic, liquid, gas—are reviewed. Advantages of the various methods of excitation are also discussed. The report concludes with some predictions of future trends in the use of laser materials.

Semiconductor Materials for High Temperatures, E. G. Bylander ..... Sep 123
What are the prospects of eventually obtaining a high-temperature transistor? This article analyzes the problems and gives some of the answers. The basic limitations on device performance are reviewed, and criteria for high-temperature semiconductor materials are developed. Processing problems are discussed, and after considering cost and reliability, the outlook for availability of devices is presented.

MATERIALS, MECHANICAL/STRUCTURAL

Filament-Wound Reinforced Plastics for Electrical Equipment, Staff Report ..... Jan 67
A study of filament winding as a technique in the design of high-strength electrical components. The design properties of materials, primarily glass-fiber-reinforced epoxies, are reviewed and interpolated. Test methods for finished structures are described and evaluated.

Rigid-Foam Structures for Shock Protection of Electronic Subassemblies, B. H. Anderson ..... Sep 90
Properties of rigid-urethane support structures, machined or molded to the contours of the individual electronic components, are assessed in terms of mechanical-energy absorption, strength-to-weight ratios, dielectric properties, humidity and temperature effects, design flexibility and manufacturing costs.

Effects of Fabrication on Design Properties of Materials, B. Bennett ..... Nov 108
The environment of processing and fabrication may degrade materials (for example, thermoplastics) and thus affect the performance of finished parts. The design engineer therefore cannot safely apply handbook values without making adequate provisions for such possible property changes. Proper parts design and quality control are necessary to reduce degradation to the minimum.

Adhesives

Adhesives for Optical and Electro-Optical Applications, I. Katz ..... Apr 161
Adhesives for bonding optical components with each other, joining optical components to non-optically active structures and fixing radioactive substances to components for identification purposes are reviewed. The materials are reviewed within the framework of Military and Federal Specifications; many are commercially available.

Metals

High-Strength Copper-Base Alloys, C. L. Bulow .... Feb 113
New high-strength copper alloys are discussed and evaluated within the framework of electrical/electronic design. Consideration is given to mechanical, electrical, thermal and corrosion-resistance characteristics.

Design Criteria for Solders in Cryogenic Environments, J. L. Christian ..... Jun 109
An increasing number of applications require the use of soldered joints in aerospace-vehicle electrical/electronic systems operating in cryogenic environments. This article reports on an investigation of the mechanical properties of thirteen different solders from 78 to −423 F, tabulates the results, and interprets their design significance.

MOTORS

Radio Interference From Carbon-Brush Operation, R. E. Nelson and J. E. Diehl ..... Jul 53
The physical phenomena underlying radio interference from rotating electrical machines are classified for discussion. Results of extensive laboratory tests made to explore the relative importance of the complex causative factors illustrate the reasoning.

Fractional-Horsepower

Ceramic Permanent-Magnet Fields for Motors, J. R. Ireland ..... Mar 86
Permanent magnets have advantages over wound fields for motors, but a simple substitution is not practical. Guidance to selection and application of ceramic-magnet materials is presented, with descriptions of resulting motor properties.

The Polarized Synchronous Motor, J. Winston ..... Jul 92
The polarized form of the small synchronous motor offers the advantage of synchronizing in only one shaft position, as required for some applications. Principles of operation of the motor are discussed and compared with those of other types of synchronous motors.

PRODUCTION AND ASSEMBLY TECHNIQUES

Bonding and Welding Techniques for Microcircuits, Staff Report ..... Mar 89
A study of feasible methods for making reliable interconnections in microelectronic packages. Three procedures (soldering, welding and heat-pressure bonding) are introduced and analyzed for effects on design specifications. A sample materials specification for welded interconnections is also presented.

Subject Classification | Month | Page

Packaging

Rigid-Foam Structures for Shock Protection of Electronic Subassemblies, B. H. Anderson ..... Sep 90
Properties of rigid-urethane support structures, machined or molded to the contours of the individual electronic components, are assessed in terms of mechanical-energy absorption, strength-to-weight ratios, dielectric properties, humidity and temperature effects, design flexibility and manufacturing costs.

SYSTEMS

Amplifier Circuits

A Review of Chopper Amplifiers, P. f. Howden ..... Jun 64
Representative chopper-amplifier circuits, suitable for measurement of extremely low voltages and currents, are discussed. D-C carrier amplifiers, chopper amplifiers with feedback, chopper-stabilized amplifiers, and chopper electrometers are compared for sensitivity, bandwidth, and other characteristics.

Negative Feedback in Current Amplifiers, R. R. Jennings ..... Jul 100
The author of a previous article on negative feedback in voltage amplifiers (December 1962) extends his treatment to include current amplifiers. Circuit configurations are presented for improving the current amplifier, and for converting it to a transconductance, transresistance, or voltage amplifier. Expressions are developed for predicting amplifier performance.

Accuracy and Stability in Operational Amplifiers, J. K. Scully..... Aug 53
Scaling and integrating amplifiers are analyzed from the viewpoints of phase and amplitude accuracy and high-frequency stability. The author discusses the interdependence of gain, phase and frequency, and suggests a method for improving accuracy through an increase in gain at high frequencies.

High-Frequency Amplifier Design Using Admittance Parameters: Part 1—Basic Concepts, G. Johnson, P. Norris and F. Opp ..... Nov 74
Advantages of using y parameters to characterize high-frequency transistors are detailed. Expressions for various forms of power gain and the Linvill and Stern stability factors are developed in terms of y parameters. An understanding of these expressions is basic to the design of high-frequency amplifiers.

High-Frequency Amplifier Design Using Admittance Parameters: Part 2—Techniques, G. Johnson, P. Norris and F. Opp ..... Dec 66
Basic gain and stability relationships developed in Part 1 of this series are applied. The Linvill chart is developed from a graphical representation of power flow through a linear active network. The principles are illustrated by design calculations for an amplifier stage using y parameters and the Linvill chart.

Analysis

"Stress Analysis" of Switching Circuit Reliability, H. F. Najjar..... Jul 68
Overall circuit and system reliability may be calculated from measured individual-component reliability by using a "stress" concept.

Pessimistic Circuit Design, N. A. Fruci..... Oct 74
A simple transistor gate circuit is used to demonstrate the pessimistic method of switching-circuit design. The resultant design is evaluated by statistical means. Distribution and variability of the basic components in the circuit are discussed and usable component parameter distributions are presented.

Root-Locus Systems Analysis, A. W. Langill, Jr..... Oct 79
Basic root-locus methods are discussed and described. The use of the Spirule graphical device is stressed. Examples are given of applications to the design of an autopilot control and a lead-lag compensation network and to polynomial factoring and network transfer-admittance calculations.

The Computer as a Design Tool—The MIT Approach, Staff Report ..... Nov 112
A computer-aided design program accepts graphical and human language input from the design engineer and puts the speed and memory of the digital computer at his disposal. Engineers may use this system with no knowledge of computer programming.

Circuit Design

Designing Bistable Trigger Circuits, A. J. Adler .... Apr 108
A method is described for accomplishing the design of a bistable trigger using complementary transistors to achieve a circuit with accurate control of the "turn-on" level, low hysteresis, and high efficiency.

Eliminating Hysteresis in the Schmitt Trigger, M. B. Leeds ..... Sep 43
Circuit design and characteristics of the Schmitt trigger are discussed. The circuit is extensively used for d-ç level detection, signal-level shifting, waveform restoration and square-wave generation. A minimum-hysteresis design procedure is detailed.

Communication

Infrared-Radiation Reference Sources, R. W. Reynolds..... Jan 46
Various types of standard radiation reference sources are described and illustrated. Their design principles and parameters, which may be varied to achieve different effects, are discussed. Use of a reference source in a calibration system is explained.

Lasers: Principles and Uses, S. A. Collins, Jr. ..... Mar 64
The laser is the equivalent of the r-f or microwave oscillator. Light applied to a Fabry-Perot cavity results in selective oscillations that produce a coherent light output in a well-collimated beam. The principles of operation, significant features and uses of lasers are described.

Applications of Varactor Diodes, R. L. Ernst and J. K. Fitzpatrick..... Sep 54
Theory of the semiconductor voltage-variable capacitor is briefly presented. Commonly used varactor parameters and their significance are described. Several representative applications—frequency multipliers, frequency converters, parametric amplifiers—are discussed, and use of the Manley-Rowe power equations is illustrated.

Infrared Detectors, F. Schwarz ..... Nov 116
Infrared detection devices including photoconductive, photoemissive and thermal devices are discussed. Emphasis is placed upon thermal detectors—semiconductor or thermistor bolometers, metal bolometers and radiation thermocouples and thermopiles.

Computer-Type Subsystems

Ferrite Memory Systems and Devices, Part 1—Systems and Single-Aperture Devices, Staff Report ..... Feb 80
A description of one, two, three and higher dimensional ferrite memory systems and the "read only" memory. Single-aperture devices discussed are the ferrite toroid, ferrite aperture plate and ferrite bead.

Ferrite Memory Systems and Devices, Part 2—Multiaperture Devices, Staff Report ..... Mar 124
Multiple-aperture ferrite devices are discussed, including transfluxor cores, the MARS device, circular and rectangular three-hole cores, coincident-flux cores, the Biax element and ferrite films. A bibliography and a table summarizing both multiple- and single-aperture devices are appended.

Subject Classification	Month	Page

Control

A Method of Approximating Phase and Attenuation, J. P. Bobis ..... Feb 117
A method of determining either attenuation or phase of a system whose transfer function is in the frequency domain when one or the other of the basic properties are known. The method is particularly useful when the gain (or phase) characteristic is equivalent to a set of confluent parabolic arcs or straight-line segments.

Feedback Techniques for Transistor Voltage Regulation, B. D. Jimerson..... Mar 76
The use of transistor feedback circuits to regulate voltage sources is analyzed in this article. A general regulation equation is developed and applied to a typical regulation network. Design considerations in feedback stability and the use of Zener-diode reference sources are discussed.

Reed Logic, L. A. Burnett ..... Mar 120
The reed switch device has reliability competitive with semiconductor devices and may be used to construct relay-type logic circuits. This article examines reed switch reliability and discusses a number of reed logic configurations.

The Direct-Drive D-C Servo, J. M. Aherne..... Apr 54
For many industrial and military purposes, the direct-drive servo has many advantages over the geared servo. These characteristics can be exploited only by the use of system components designed for direct-drive servo application. System characteristics and their effect on amplifier and other component specifications are demonstrated.

Adaptive Control Systems, V. W. Eveleigh..... Apr 79
A survey of the most recent developments in the field of control systems which is currently demanding the greatest amount of the designer's attention. Types of systems are categorized and explained in terms of methods of design and analysis.

Linear Control Using ON-OFF Controllers, A. A. Sorensen ..... Apr 99
The advantages and disadvantages of various methods of pulse modulation for the control of devices in a linear manner are presented. It is shown that no one method is perfect or will do all things which might be desired for the system. However, each technique is suitable in certain cases as a best solution.

Dual-Mode Control Systems, R. J. Lahr, H. R. Weed and F. C. Weimar ..... May 98
This article extends discussions of linear and nonlinear control systems to a type of control system which uses both modes of operation. The dual-mode approach to control systems is presented, and the results of experiments to determine optimum conditions of operation are given.

A Review of Chopper Amplifiers, P. f. Howden ..... Jun 64
Representative chopper-amplifier circuits, suitable for measurement of extremely low voltages and currents, are discussed. D-C carrier amplifiers, chopper amplifiers with feedback, chopper-stabilized amplifiers, and chopper electrometers are compared for sensitivity, bandwidth, and other characteristics.

The Switching Mode in D-C Voltage Regulation, A. Lambert..... Jun 78
The modulation of power in switching-type d-c voltage regulators is discussed. Several switching-type systems are presented. The concepts involved apply equally well to continuous modulation of power in equipment such as servo systems and adjustable-speed drives.

Design Factors for Pneumatic Servomechanisms, H. B. Diamond ..... Aug 40
The relative merits of pneumatic and hydraulic servomechanisms are considered, indicating the fields of greatest usefulness for each type. Detailed analysis is then presented of pneumatic flow-control valve configurations and characteristics, and of application of valves in systems.

Turn-Off Silicon Controlled Rectifiers, H. F. Storm. Oct 62
The operation of turn-off SCR's is discussed. Consideration is given to turn-off current gain, speed, problems with larger currents, and applications. A circuit model with an equivalent-current bypass is used to illustrate the turn-off mechanism.

Digital Motor-Speed Control, W. F. Shoop ..... Oct 68
Accuracy of speed control of an a-c drive to within ± 0.01 per cent or better of the desired speed has been obtained using pulse techniques to generate a square wave of precisely controlled frequency. In the particular case described the speed of a small hysteresis synchronous motor is controlled by means of a high-speed digital counter, a high-frequency oscillator and logic circuits.

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The Rotating Amplifier: Operating Principles, E. Erdelyi..... Nov 59
Operating principles of the rotating amplifier are analyzed, giving a basis for exploring the characteristics of the various forms of this special-purpose d-c machine. Commercially available variations of the basic machine, and their applications, will be described in an article to follow.

The Rotating Amplifier: Applications, E. Erdelyi .. Dec 55
Commercially available forms of the major classes of rotating amplifiers are examined and their merits compared; their operating principles were described in the article in the November issue by the same author. Specific drive-control systems employing these machines are used to illustrate their fields of application.

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Sequential Switching Logic, M. D. Wilt ..... Dec 50
Design of sequential switching circuits using flip-flops and diode gates is discussed. A new technique for minimizing components is presented along with standard factoring methods using Karnaugh maps and Boolean minimization.

Drive

The Direct-Drive D-C Servo, J. M. Aherne..... Apr 54
For many industrial and military purposes, the direct-drive servo has many advantages over the geared servo. These characteristics can be exploited only by the use of system components designed for direct-drive servo application. System characteristics and their effect on amplifier and other component specifications are demonstrated.

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Subject Classification	Month	Page
Adjustable-Speed A-C Drive with SCR Frequency Inverters, T. E. Usher and C. D. Beck ..... The principles underlying systems for obtaining variable speed using a-c motors and adjustable frequency are outlined. Practical methods of obtaining frequency control using SCR circuits are then described. Advantages and limitations of the system are discussed.	Aug	58
Digital Motor-Speed Control, W. F. Shoop ..... Accuracy of speed control of an a-c drive to within ± 0.01 per cent or better of the desired speed has been obtained using pulse techniques to generate a square wave of precisely controlled frequency. In the particular case described the speed of a small hysteresis synchronous motor is controlled by means of a high-speed digital counter, a high-frequency oscillator and logic circuits.	Oct	68
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General

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Passive Circuits

Design of a Pulse-Narrowing Network, H. M. Sierra ..... This article describes a network design by synthesis methods. The resultant network is capable of doubling magnetic-tape recording density.	Sep	38

Recording

Design of a Pulse-Narrowing Network, H. M. Sierra ..... This article describes a network design by synthesis methods. The resultant network is capable of doubling magnetic-tape recording density.	Sep	38

Semiconductor Circuits

Circuits for Generating a Long Time Base, H. Anway ..... Systems are discussed for producing linear sawtooth sweeps with periods as long as several days. A unique level-sensing flip-flop is described and linearity calculations are given.	Aug	96

TEST AND MEASUREMENT

Fundamentals of Measurement, A. G. McNish ..... The historical development of measurement systems and standards is examined, beginning with an elucidation of the conceptual basis of measurement. Techniques of measurement, including aspects of precision and accuracy, are described. The basic quantities of mass, time and temperature are examined, as are the other physical quantities, including the electrical. The impact of contemporary technology on measurement concepts and techniques is discussed. The use of wavelengths of given elements for standards is an example.	May	113
Basic Low-Frequency A-C Measurements—2, J. B. Kelley ..... The first half of this article, which appeared in our May issue, established the basis for fundamental a-c measurements: unit standards. Operating principles and calibration techniques for primary a-c measuring instruments are now presented.	Jun	103

Components

Infrared-Radiation Reference Sources, R. W. Reynolds ..... Various types of standard radiation reference sources are described and illustrated. Their design principles and parameters, which may be varied to achieve different effects, are discussed. Use of a reference source in a calibration system is explained.	Jan	46
Ball Bearings Designed to Meet Special Application Requirements—1, Frank J. Oliver ..... Part 1 of series deals with the development of miniature and instrument precision ball bearings, and the instruments available to evaluate their performance in terms of starting and running torque, vibration and noise. Gyro bearings are discussed, as well as smooth-running and quiet bearings of larger size for motors, spindles and appliances.	Feb	56
A Second Evaluation of the Industrial "300-Volt" Relay, W. Ketterer and W. Frank ..... Results of electrical and mechanical life tests are reported on three types of compact machine-tool relays with contacts evaluated in four operational modes: make contact, break contact, seal in and interlock other circuits. With continuing improvements in design, acceptable reliability for industrial service is predicted.	Mar	171
Specification and Testing of Shielded Transformers, B. I. Sommer and G. W. Plice ..... Optimization of transformer performance for applications involving low-level signals is discussed. The most important test techniques are described and specification is related to materials and cost considerations.	May	102
Statistical Circuit Analysis Based on Part Test Data, F. A. Applegate ..... The reliability of a circuit is no better than that of its component parts. An accurate and efficient part testing program is described and its results are then applied to the statistical analysis of the worst-case circuit design in which the parts are to be used.	May	140
Synchro and Resolver Evaluation and Test Equipment, Staff Report ..... Guidance is offered by experts among both users and designers of test equipment for evaluating synchros and resolvers. Various controversial questions are explored, relating to both test methods and to the standardizing—and the lack of it—in the components. Important specifications are listed and discussed, and sources of detailed information are given.	May	201
Graphical Methods of Solving Thermoelectric-Heat-Pump Problems, P. C. Watson ..... A test procedure is outlined for producing characteristic data of heat-pump modules as the basis of working charts for cooling-systems design. Six examples and their solutions are presented.	Jun	74

Environmental

Specification of Shock Tests, C. E. Crede ..... Analyses of various shock motions and the resulting responses of equipment are presented to derive requirements for shock-testing machines. Various existing testing machines are described and compared. Comments on the use of testing machines as well as methods of improvising shock tests are included.	May	82

Subject Classification	Month	Page
Instrumentation for Environmental Chambers, F. H. Gardner The measurement and control of conditions of temperature, humidity and simulated altitude in environmental test chambers establish the validity of tests. Precautions to observe in selecting combinations of instruments and controls are discussed.	Sep	50
The Nature of Materials Failure Under Space Conditions, Staff Report Many aspects of space environments are more subtle than the much-discussed high-energy radiation. Some of these are similar to "normal-condition" hazards, but differ in severity. Certain test techniques not commonly known must be used for significant study of these space effects on materials.	Sep	128
Instrumentation for Shock Testing, D. Arlidge and R. Morse The increasing rigor and complexity of shock-resistance requirements are leading to more elaborate shock-testing methods. The merits and ranges of application of the various available types of shock generators, accelerometers and readout devices are compared.	Dec	96
General		
Digital Measurements of Frequency and Time, G. J. Himler and R. Chafin This article describes methods of using a group of digital circuit modules for various frequency and period measurements. The effects of variations in gating, time base and triggering are related to measurement accuracy and calibration.	May	93
Computer Methods for Analyzing Test Data, G. Diaz The digital computer offers new means of evaluating test data. Standard statistical measures can be calculated with great speed, and tabular values accurately interpolated. Mathematical functions which closely "fit" the test data can be constructed by methods which would be impractical by slow hand calculation.	May	152
Temperature Measurement in Moving Fluids, R. P. Benedict Thermodynamic states encountered in moving fluids are considered in order to evaluate the validity of temperature measurements in such fluids. Idealized and real moving fluids and temperature probes are investigated, and correction factors are derived for making measurements under various conditions.	Sep	56
Principles and Techniques		
Basic Low-Frequency A-C Measurements—1, J. B. Kelley In electro-technology, absolute references for test and measurement are d-c. The author of our earlier d-c measurement articles carries our program toward the next important step: fundamentals of power-frequency test and measurement. This first of two parts discusses unit standards: capacitance and inductance.	May	129
Radio-Frequency Voltage Measurement, B. P. Hand Basic principles of devices, instruments and techniques are described, covering frequency range from 100 kc to 1 Gc. Principles of thermal converters—resistance elements, thermistors and barretters—and other transfer devices are discussed. Commercial types of r-f voltmeters are distinguished. Calibration techniques and highest accuracy standards are described in detail.	Oct	109
The Generation of Thermocouple Reference Tables, R. P. Benedict A technique using the second-degree Lagrange interpolation equation is presented for generating useful thermocouple reference tables. Since new reference tables actually cannot be generated, the technique shows a way to generate values which conform with the established tables and which can be interpolated and stored in computer memory systems.	Nov	80
Systems		
Statistical Circuit Analysis Based on Part Test Data, F. A. Applegate The reliability of a circuit is no better than that of its component parts. An accurate and efficient part testing program is described and its results are then applied to the statistical analysis of the worst-case circuit design in which the parts are to be used.	May	140
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Research Notes

Nonmetallic Fiber-Reinforced Metal Composites	Jan	11
Corrosion of Metallic Surfaces	Jan	12
New Advances in Laser Development	Jan	13
Electrical Conductivity of Ceramic Bodies	Feb	11
Laser Wavelength Determination	Feb	12
Aromatic Imide Polymers for Electrical Insulation	Feb	12
New Prefixes for Units	Feb	13
Research Studies in Man-Machine Systems	Mar	11
Rotation of Ultrasonic Waves by a Magnetic Field	Mar	11
Large-Diameter Silicon Single Crystal	Mar	12
A-F Pattern Recognition with Optic Fibers	Mar	12
Ring Laser Detects Motion	Apr	11
Optical Storage of Radar Information	Apr	11
Photoionization and Electrical Breakdown	Apr	12
Microminiature Glass Wires	Apr	13
Solid-State Circuits Conference Highlights	May	13
Digital Applications of Thermoplastic Recording	May	14
The Solid Matrix Materials of Fluid-Amplification Systems	Jun	11
The Hall Effect Applied to Nondestructive Testing	Jun	12
Experimental Mercury Contacts	Jun	16
The Nernst Generator: A Thermomagnetic Energy Converter	Jul	11
Physical Properties of Thin Films	Jul	13
Thermal Shock Problems in Flexible Encapsulants	Aug	11
Basic Theory—Particle Gyroscope	Aug	12
Electrical Insulation for Hermetically Sealed Systems	Sep	13
High-Current Metal-Fiber Electrical Contacts	Sep	14
Cracking in Iron-Nickel-Cobalt Alloy Wire	Oct	11
New Developments in Learning Systems	Oct	13
System for Conversion of Radiation Units	Oct	13
Superconductive Columbium-Tin Wire	Nov	11
Low-Temperature-Coefficient-of-Resistance Alloys	Nov	12
Superconductivity and Solid-State Devices	Nov	13
The Significance of Materials Science	Dec	11
Materials for 2000-C Thermionic Emitters	Dec	12
Semiautomatic Fault-Isolation System	Dec	13

Editorials

	Month	Page
The Materials/Design Interface — *A. E. Javitz*	Jan	45
A Broad Look at R & D — *F. J. Oliver*	Feb	55
Cryogenic Circuit Hiatus — *H. Falk*	Mar	63
Toward More Advanced Degrees — *F. J. Oliver*	Apr	53
Test and Measurement—Design Engineering Functions — *F. J. Oliver*	May	81
Revitalizing the Mature Engineer — *F. J. Oliver*	Jun	51
Experience Required — *A. E. Rudahl*	Jul	47
The Art of Engineering — *A. E. Rudahl*	Aug	39
Materials—The Basic Interdiscipline — *A. E. Javitz*	Sep	37
Technical Meetings: Information or Indoctrination? — *H. Falk*	Oct	55
Promoting Transfer of Technology — *F. J. Oliver*	Nov	57
Who Needs Mathematics? — *H. Falk*	Dec	49

Design Trends

January 1963

Resistance Changes in Wirewound Potentiometers 100
Design of Windings for Small Hysteresis Motors 101
Machine-Tool-Control Relay Designed for Compactness 104
Complex A-C Potentiometer 104
Design Applications of Rhenium and Rhenium Alloys 106
Cathode-Ray Tube Has Window Display 108
Diallyl Phthalate Resin for Programming Plugboards 108

February 1963

Memory Circuits Using NOR Logic 120
Stable Differential Thermocouple Voltmeter Uses Zener Diode Reference 121
Reinforced Carbon-Graphite Bearing Cages Designed for Environmental Extremes 122
The Solid-State Switch, A-C Line Regulator 122
Memory-Drum Start-Up Mechanism 128
Memory Device Operates on Electrolytic Principle 128

March 1963

Design Data for Semiconductor Thermoelectric Devices 132
Vapor-Phase Cooling of High-Power Equipment 133
Silicon *vs* Selenium for High-Current, Low-Voltage Power 136
A Design Criterion for Regulated Power Supplies 138
High-Precision Transformer Summing Network 140
Resin Bonding of Motor Rotors 142

April 1963

Motor and Oscillator Integrated for Brushless Operation 118
Protected SCR Drives Rated Up to 125 Hp 118
Multiaperture-Core Logic Used in Telemetering System 120
Use of the Gertsch Method for Transformer Ratio 122
Traction-Motor Control Using Pulse-Width Modulation 124
Controlled-Tension Fastener 126
Magnetic Diode Tester 126

May 1963

Testing Electronic Equipment for Power Frequency Noise 156
Gearless Low-Speed Motor Uses Impulse Principle 157
The Spectrum Analyzer as a Computer Element 158
Determining the Operating Temperature of an A-C Coil 160
Hermetically Sealed Servomotor 162
Impact Shock Testing of Transistors 164

June 1963

A Test Investigation of the Equivalence of Acoustically and Mechanically Induced Vibrations 118
Microminiature Helical Quartz Springs 119
SCR Bias Stabilization 119
Matching Oscillograph Chart Paper to Viscous Ink 120
Piezoelectric Pickoffs in Rate Gyro 122
Sweep Generator Calibration by Saturable Reactor 122
Cesium Atomic Beam Tube 124
Broadband UHF Transistor Amplifiers 124
Transistor Process Improves Breakdown Voltage 128
Thermal Relay is Voltage-Sensing 128

July 1963

Measurement of Base-Resistance Collector-Capacitance Product 104
Compressor Overload Protector Has New Hermetic Terminal 106
Printed Circuits in Airborne Electric Systems 106
Stabilizing the Unijunction Transistor 110
Punched-Card Test Memory 112

August 1963

Circuits for Generating a Long Time Base 96
Rotating-Race Gyroscope Bearings 98
Changeable Poles for 300-Volt Relays 102
Solid-State Clutch Control 102

September 1963

Varactor-Diode Temperature Compensation 204
Interconnections for Microcircuits 205
SCR Control for Universal Motors 205
Single-Reversal Traveling-Wave Tube 206
Effect of Temperature on Life of Carbon-Composition Resistors 208
Packaging a Telemetry Amplifier 210
Planetary Ball-Bearing Speed Increaser 212

October 1963

Q Multiplication Using Transistors 118
Alphanumeric Readout Tube with Latching Memory 119
Tester for Forward and Reverse SCR Breakdown 120
Electrically Oscillated Gimbal Bearing 122
Effect of Temperature and Current on Zener Breakdown 122
Nomograph for Converting FET Noise Characteristics 126

November 1963

Photocell Technique for Linear Measurements 120
Inductive-Energy Storage 121
Frequency Comparator Has Increased Precision 122
Transient Suppression with Controlled-Avalanche Rectifiers 124
High-Torque Timing Motor 126
Impedance Chart 126

December 1963

Selecting Transistors for Coil Drivers 106
Gray-Code Conversion 107
Choosing Current for Thermoelectric Cooling 108
Fuel-Cell Pressure Controller 110
Automatic Flip-Flop Reset Circuit 110
Centerwind-Tension Control System 112

Authors' Index

	Month	Page
A		
Adams, H. S. Problems In Insulated Wire And Cable In Space-Vehicle Systems	Sep	133
Adler, A. J. Designing Bistable Trigger Circuits	Apr	108
Aherne, J. M. The Direct-Drive D-C Servo	Apr	54
Alban, C. F. Design of Bimetal Actuators *for snap-action and constant-friction devices*	Apr	75
Amlinger, P. R. Graphical Analysis of Transfer Functions	Jan	71
Anderson, B. H. Rigid-Foam Structures For Shock Protection Of Electronic Subassemblies	Sep	90
Anderson, F. B. Solution of Quadratic, Cubic and Quartic Equations	Jan	53
Network Analysis by Kreer Delta-*T* Transformation	Jul	62
Applegate, F. A. Statistical Circuit Analysis Based on Part Test Data	May	140
Arlidge, D. B. Instrumentation For Shock Testing	Dec	96
ASME Design Engineering Program	May	8
B		
Barker, R. C. Nonlinear Magnetics	Mar	95
Beck, C. D. Adjustable-Speed A-C Drive with SCR Frequency Inverters	Aug	58
Beekman, E. High-Stability Magnetic Tape For Data-Processing Systems	Dec	91
Benedict, R. P. Thermodynamics of Compressible Fluids	Feb	85
Thermodynamics of Constant-Density Fluids	Apr	70
Temperature and Its Measurement	Jul	71
Temperature Measurement in Moving Fluids	Oct	56
The Generation of Thermocouple Reference Tables	Nov	80
Analog Simulation	Dec	73
Bennett, B. Effects of Fabrication on Design Properties of Materials	Nov	108
Bishop W. B. Use of Failure Statistics in Design	Jul	97
Bobis, J. P. A Method of Approximating Phase and Attenuation	Feb	117
Borst, D. W. Semiconductor Rectifier Diodes and Controlled Rectifiers	Feb	106
Brodersen, R. K. The Toroidal Displacement Transducer	Mar	115
Bulow, C. L. High-Strength Copper-Base Alloys	Feb	113
Burnett, L. A. Reed Logic	Mar	120
Bylander, E. G. Semiconductor Materials for High Temperatures	Sep	123
C		
Chafin, R. L. Digital Measurements of Frequency and Time	May	93
Christian, J. L. Design Criteria for Solders in Cryogenic Environments	Jun	109
Collins, S. A., Jr. Lasers: Principles and Uses	Mar	64
Conceicao, P. H. The Computer as a Design Tool	Jul	48
Constant, P. C. Matrix Computation Methods	Nov	68
Crede, C. E. Specification of Shock Tests	May	82
D		
Diamond, H. B. Design Factors for Pneumatic Servomechanisms	Aug	40
Diaz, G. Computer Methods for Analyzing Test Data	May	152
Diebold, E. J. Semiconductor Rectifier Diodes and Controlled Rectifiers	Feb	106
Diehl, J. E. Radio Interference from Carbon Brush Operation	Jul	53
E		
Eisenberg, M. Applications Analysis of New R-F Ferrites	Jul	87
Erdelyi, E. The Rotating Amplifier: Operating Principles	Nov	58
The Rotating Amplifier: Applications	Dec	55
Ernst, R. L. Applications of Varactor Diodes	Sep	54
Eveleigh, V. W. Adaptive Control Systems	Apr	79
F		
Falk, H. The Computer as a Design Tool	Jul	48
New Relay Developments	Jul	143
Fitzpatrick, J. K. Applications of Varactor Diodes	Sep	54
Frank, W. A Second Evaluation of The Industrial "300-Volt" Relay	Mar	171
Frey, J. The A-C Tachometer	Aug	88
Fruci, N. A. Pessimistic Circuit Design	Oct	74
G		
Gardner, F. H. Instrumentation for Environmental Chambers	Sep	50
Getgen, L. E. Application of Matrix Algebra to Circuit Design	Feb	70
Glaser, A. Electric and Magnetic Fields	Nov	83
Gregor, L. V. The Materials of Thin-Film Devices	Sep	95

	Month	Page
H		
Halaby, S. A.		
The Materials of Thin-Film Devices	Sep	95
Hand, B. P.		
Radio-Frequency Voltage Measurements	Oct	109
Haun, R. D.		
Laser Materials And Devices—A Research Report	Sep	63
Hellstrom, M. J.		
The Exponential RC Filter	Dec	62
Himler, G. J.		
Digital Measurements of Frequency and Time	May	93
Holden, P.		
Reliability of the Field-Effect Transistor	Jul	58
Howden, P. f.		
A Review of Chopper Amplifiers	Jun	64
Hutchison, T. C.		
Principles of Optics	Jun	83
I		
Ireland, J. R.		
Ceramic Permanent-Magnet Fields for Motors	Mar	86
J		
Javitz, A. E.		
Dielectrics in 1962: Phenomena, Materials, Devices	Jan	91
Special Report: Electrical/Electronic Materials	Sep	61
Perspectives in Insulation—Application Trends and Problems	Sep	84
Jennings, R. R.		
Negative Feedback in Current Amplifiers	Jul	100
Jimerson, B. D.		
Feedback Techniques for Transistor Voltage Regulation	Mar	76
Johnson, G.		
High-Frequency Amplifier Design Using Admittance Parameters: Part 1—Basic Concepts	Nov	74
High-Frequency Amplifier Design Using Admittance Parameters: Part 2—Techniques	Dec	66
K		
Katz, I.		
Adhesives for Optical and Electro-Optical Applications	Apr	161
Kavounas, T.		
The Nature of Ferroresonance	Aug	49
Kelley, J. B.		
Basic Low-Frequency A-C Measurements—1	May	129
Basic Low-Frequency A-C Measurements—2	Jun	103
Ketterer, W.		
A Second Evaluation of The Industrial "300-Volt" Relay	Mar	171
Key, J.		
Pulsed Nuclear Radiation Effects on Electronic Components and Materials	May	106
Knights, A. F.		
Choice of Fluids for Cooling Electronic Equipment	Jun	57
L		
Lahr, R. J.		
Dual-Mode Control Systems	May	98
Lambert, A.		
The Switching Mode in D-C Voltage Regulation	Jun	78
Langhill, A. W., Jr.		
Multivariant Function Generation	Jun	52
Root-Locus Systems Analysis	Oct	79
Lascaro, C. P.		
Pulsed Nuclear Radiation Effects on Electronic Components and Materials	May	106
High-Stability Magnetic Tape for Data-Processing Systems	Dec	91
Leeds, M. B.		
Eliminating Hysteresis in the Schmitt Trigger	Sep	43
Lion, K. S.		
Survey of Pressure Transducers—Principles and Design	Jan	50
Longmire, D. E.		
Magnetic Shielding Practice in Electronic Packaging	Jan	63
M		
McNish, A. G.		
Fundamentals of Measurement	May	113
Malinofsky, W. W.		
Applications Analysis of New R-F Ferrites	Jul	87
Manteuffel, E. W.		
A Shunt-Loaded Magnetic Amplifier	Apr	112
Mathes, K. N.		
Electrical Insulation At Cryogenic Temperatures	Sep	72
Morse, R. F.		
Instrumentation for Shock Testing	Dec	96
N		
Najjar, H. F.		
"Stress Analysis" of Switching-Circuit Reliability	Jul	68
Nelson, R. E.		
Radio Interference from Carbon-Brush Operation	Jul	53
Norris, P.		
High-Frequency Amplifier Design Using Admittance Parameters: Part 1—Basic Concepts	Nov	74
High-Frequency Amplifier Design Using Admittance Parameters: Part 2—Techniques	Dec	66
O		
Oliver, F. J.		
Ball Bearings Designed to Meet Special Application Requirements—1	Feb	56
Ball Bearings Designed to Meet Special Application Requirements—2	Mar	80
Ball Bearings Designed to Meet Special Application Requirements—3	Apr	102
Opp, F.		
High-Frequency Amplifier Design Using Admittance Parameters: Part 1—Basic Concepts	Nov	74
High-Frequency Amplifier Design Using Admittance Parameters: Part 2—Techniques	Dec	66
P		
Parton, K. C.		
The Computer as a Design Tool	Jul	48
Pendleton, W. W.		
Advanced Magnet-Wire Systems	Oct	95
Perry, C. C.		
Design of Bimetal Actuators *for snap-action and constant-friction devices*	Apr	75
Phillips, T. A.		
A Shunt-Loaded Magnetic Amplifier	Apr	112
Plice, G. W.		
Specification and Testing of Shielded Transformers	May	102

R

Reynolds, R. W.
Infrared-Radiation Reference Sources — Jan — 46

Rodrigue, G. P.
Magnetic Materials for Millimeter Wave Devices — Sep — 78

Royal, E. L.
Elements of a Practical Reliability-Engineering Program — Jan — 59

Rubens, S. M.
The Materials of Thin-Film Devices — Sep — 95

Rusch, A.
High-Stability Magnetic Tape for Data-Processing Systems — Dec — 91

Ruzicka, J. E.
Vibration Control — Aug — 63

S

Schlosser, W.
Pulsed Nuclear Radiation Effects on Electronic Components and Materials — May — 106

Schultz, A. J.
Counter-Tube Drive Circuits — Aug — 90

Schwarz, F.
Infrared Detectors — Nov — 116

Scully, J. K.
Accuracy and Stability in Operational Amplifiers — Aug — 53

Severin, H.
Ferrites—Materials and Applications — May — 146

Shoop, W. F.
Digital Motor-Speed Control — Oct — 68

Sierra, H. M.
Design of a Pulse-Narrowing Network — Sep — 38

Silverman, D.
Voltage-Driven Hall Generators — Jun — 113

Smith, S. L.
Color-Coded Displays for Data-Processing Systems — Apr — 63
Man-Computer Information Transfer — Aug — 83

Sommer, B. I.
Specification and Testing of Shielded Transformers — May — 102

Sorenson, A. A.
Linear Control Using On-Off Controllers — Apr — 99

Staff Reports (see also under H. Falk, A. E. Javitz and F. J. Oliver)
Filament-Wound Reinforced Plastics for Electrical Equipment — Jan — 67
Electromagnetic Delay Lines — Jan — 143
Ferrite Memory Systems and Devices, Part 1—Systems and Single-Aperture Devices — Feb — 80
Bonding and Welding Techniques for Microcircuits — Mar — 89
Ferrite Memory Systems and Devices, Part 2—Multi-aperture Devices — Mar — 124
Synchro and Resolver Evaluation and Test Equipment — May — 201
The Nature of Materials Failure Under Space Conditions — Sep — 128
Microelectronic Components: Capability and Availability — Oct — 103
The Computer as a Design Tool—The MIT Approach — Nov — 112

Steltz, W. G.
Thermodynamics of Compressible Fluids — Feb — 85
Thermodynamics of Constant-Density Fluids — Apr — 70

Stockman, H. E.
Transistor Transformation Matrix — Sep — 46

Storm, H. F.
Turn-Off Silicon Controlled Rectifiers — Oct — 62

Sueker, K.
Protecting Silicon Rectifiers from Transient Overloads — Nov — 105

T

Townsend, R.
Digital-Computer Iterative Method — Dec — 102

U

Usher, T. E.
Adjustable-Speed A-C Drive with SCR Frequency Inverters — Aug — 58

W

Warner, A. J.
Application Problems in Electrical Insulation—1 — Feb — 101
Application Problems in Electrical Insulation—2 — Mar — 71

Watson, P. C.
Graphical Methods of Solving Thermoelectric Heat-Pump Problems — Jun — 74

Weed, H. R.
Dual-Mode Control Systems — May — 98

Weimer, F. C.
Dual-Mode Control Systems — May — 98

Wheeler, N.
Survey of Electrochemical Batteries — Jun — 68

Wilt, M. D.
Sequential Switching Logic — Dec — 50

Winston, J.
The Polarized Synchronous Motor — Jul — 92

Z

Zito, R., Jr.
Dynamic Behavior of a Thermoelectric Heat Pump — Feb — 64

Alphabetical Subject Cross Index

Subject	*Classification*
A	
Acoustical Insulation	Materials, Mechanical/Structural (*Thermal and Acoustical Insulation*)
Adhesives	Materials, Mechanical/Structural
Automatic Assembly	Production and Assembly Techniques
B	
Batteries	Components, Electrical/Electronic
Bearings	Components, Mechanical/Structural
Boolean Algebra	Science & Engineering (*Mathematics*)
Brushes	Components, Electrical/Electronic (*Contact Devices*)
C	
Capacitors	Components, Electrical/Electronic
Casting Resins	Materials, Electrical/Electronic (*Electrical Insulation and Dielectrics*)
Castings	Materials, Mechanical/Structural (*Metals*)
Ceramic Dielectrics	Materials, Electrical/Electronic (*Electrical Insulation and Dielectrics*)
Ceramic-Metals	Materials, Mechanical/Structural (*Composite Materials*)
Cements	Materials, Mechanical/Structural (*Adhesives*)
Circuit Analysis	Science & Engineering (*Network Analysis*)
Circuit Breakers	Components, Electrical/Electronic (*Protective Devices*)
Clad Metals	Materials, Mechanical/Structural (*Metals*)
Coaxial Cable	Components, Electrical/Electronic (*Wire and Cable*)
Commutators	Components, Electrical/Electronic (*Contact Devices*)
Component Failure	Design Considerations (*Reliability*)
Component Testing	Test and Measurement
Composite Materials	Materials, Mechanical/Structural
Computer Design	Systems (*Modular Subsystems*)
Conductive Plastics	Materials, Electrical/Electronic (*Conductor Materials*)
Conductive Rubber	Materials, Electrical/Electronic (*Conductor Materials*)
Conductor Materials	Materials, Electrical/Electronic
Connections	Production and Assembly Techniques (*Soldering and Solderless Techniques*)
Connectors	Components, Electrical/Electronic (*Wiring Devices*)
Contact Devices	Components, Electrical/Electronic
Contact Materials	Materials, Electrical/Electronic (*Contact Materials*)
Control Instruments	Systems (*Control*)
Cooling	Heat Flow
Corona Effects	Test and Measurement (*Materials*)
D	
Delay Lines	Components, Electrical/Electronic (*Storage Devices*)
Diodes	Components, Electrical/Electronic (*Semiconductor Devices*)
Drive Elements	Systems (*Drives*), also Components, Mechanical/Structural
E	
Elastomers	Materials, Mechanical/Structural (*Nonmetallic Materials*)
Electrical Drives	Systems (*Drives*)
Electrical Insulation and Dielectrics	Materials, Electrical/Electronic
Electrodeposited Coatings	Materials, Mechanical/Structural (*Protective Coatings*)
Electronic Apparatus Design	Product Design Case History
Electron Tubes	Components, Electrical/Electronic
Embedded Circuits and Componets	Production and Assembly Techniques
Encapsulation	Production and Assembly Techniques (*Embedded Circuits and Components*)
Engineering Psychology	Design Considerations (*Human Factors*)
Environmental Effects	Design Considerations
Environmental Tests	Test and Measurement (*Environmental*)
Equipment Failure	Design Considerations (*Reliability*)
F	
Fasteners	Components, Mechanical/Structural
Felt	Materials, Mechanical/Structural (*Nonmetallic Materials*)
Ferrites	Materials, Electrical/Electronic (*Magnetic Materials*)
Finishes	Materials, Mechanical/Structural (*Protective Coatings*)
Flexible Insulation	Materials, Electrical/Electronic (*Electrical Insulation and Dielectrics*)
Fungicidal Treatment	Materials, Mechanical/Structural (*Protective Coatings*)
Fuses	Components, Electrical/Electronic (*Protective Devices*)
G	
Gaseous Dielectrics	Materials, Electrical/Electronic (*Electrical Insulation and Dielectrics*)
Gaskets	Components, Mechanical/Structural (*Seals and Gaskets*)
Gearmotors	Motors (*Special*)
Gears and Pinions	Components, Electrical/Electronic, also Systems (*Mechanical*)
Glass Dielectrics	Materials, Electrical/Electronic (*Electrical Insulation and Dielectrics*)
H	
Hermetic Sealing	Production and Assembly Techniques
Hookup Wire	Components, Electrical/Electronic (*Wire and Cable*)
Housings	Components, Mechanical/Structural
Human Factors Engineering	Design Considerations
Humidity Effects	Design Considerations (*Environmental Effects*)
I	
Impregnation	Production and Assembly Techniques (*Embedded Circuits and Components*)
Inductors	Components, Electrical/Electronic (*Magnetic Components*)
Industrial Machinery Design	Product Design Case History
Instrument Applications	Test and Measurement
Instrument Design	Product Design Case History, also Instruments and Test Equipment (*Design*)
Instrument Generators	Components, Electrical/Electronic (*Transducers*)
Insulation Testing	Test and Measurement (*Materials*)
International Standards	Specifications and Standards
L	
Laminates, Plastics	Materials, Electrical/Electronic (*Electrical Insulation and Dielectrics*)
Liquid Dielectrics	Materials, Electrical/Electronic (*Electrical Insulation and Dielectrics*)
Lubricants	Materials, Mechanical/Structural (*Nonmetallic Materials*)

Subject	Classification
M	
Magnetic Amplifiers	Systems (*Control*) also Components, Electrical/Electronic (*Magnetic Components*)
Magnetic Core Memories	Components, Electrical/Electronic (*Storage Devices*)
Magnetic Materials	Materials, Electrical/Electronic
Magnetic Recording	Components, Electrical/Electronic (*Transducers*), also Systems (*Recording*)
Magnet Wire	Components, Electrical/Electronic (*Wire and Cable*)
Maintainability	Design Considerations
Materials Testing	Test and Measurement
Mechanical Drives	Systems (*Mechanical*) also Components, Mechanical/Structural (*Drive Elements*)
Metalized Parts	Materials, Mechanical/Structural (*Composite Materials*)
Metal-Plastics Sheet	Materials, Mechanical/Structural (*Composite Materials*)
Metals	Materials, Mechanical/Structural
Meters, Panel-Type	Components, Electrical/Electronic
Microcircuit Assemblies	Components, Electrical/Electronic
Miniaturization	Design Considerations
Modular Construction	Design Considerations (*Miniaturization*)
N	
Nomographs	Science & Engineering (*Mathematics*)
Nonmetallic Materials	Materials, Mechanical/Structural
Nuclear Radiation Effects	Design Considerations (*Environmental Effects*)
P	
Packaging, Electronic	Production and Assembly Techniques
Pickups, Electrical	Components, Electrical/Electronic (*Transducers*)
Plastics, Fabricated	Materials, Mechanical/Structural (*Nonmetallic Materials*)
Plastics, Insulation	Materials, Electrical/Electronic (*Electrical Insulation and Dielectrics*)
Plastics, Molded	Materials, Mechanical/Structural (*Nonmetallic Materials*)
Plated Coatings	Materials, Mechanical/Structural (*Protective Coatings*)
Porcelain Enamel	Materials, Mechanical/Structural (*Protective Coatings*)
Potentiometers	Components, Electrical/Electronic
Potting	Production and Assembly Techniques (*Embedded Circuits and Components*)
Powder Metal Parts	Materials, Mechanical/Structural (*Metals*)
Power Generators	Systems (*Drives*)
Printed Circuits	Components, Electrical/Electronic
Printed Wiring	Production and Assembly Techniques
Printed Wiring Board	Components, Electrical/Electronic (*Printed Circuits*)
Production Tests	Test and Measurement
Protective Coatings	Materials, Mechanical/Structural
Protective Devices	Components, Electrical/Electronic
Q	
Quality Control	Test and Measurement
R	
Radio Noise and Interference	Design Considerations
Recording Instruments	Instruments and Test Equipment, also Systems (*Recording*)
Rectifiers	Components, Electrical/Electronic (*Semiconductor Devices*)
Relays	Components, Electrical/Electronic (*Contact Devices*)
Reliability	Design Considerations
Resistance Wire	Materials, Electrical/Electronic (*Conductor Materials*)
Resistors	Components, Electrical/Electronic
Rigid Insulation	Materials, Electrical/Electronic (*Electrical Insulation and Dielectrics*)
S	
Sealants	Materials, Mechanical/Structural (*Adhesives*)
Seals and Gaskets	Components, Mechanical/Structural
Semiconductor Devices	Components, Electrical/Electronic
Sensing Elements	Components, Electrical/Electronic (*Transducers*)
Servos	Systems (*Control*)
Sheet Metals	Materials, Mechanical/Structural (*Metals*)
Shielding Devices	Components, Electrical/Electronic
Shock and Vibration	Design Considerations (*Environmental Effects*)
Shock and Vibration Isolators	Components, Mechanical/Structural
Slip Rings	Components, Electrical/Electronic (*Contact Devices*)
Sockets	Components, Electrical/Electronic (*Wiring Devices*)
Soldering and Solderless Techniques	Production and Assembly Techniques
Solenoids	Components, Electrical/Electronic (*Magnetic Components*)
Springs	Components, Mechanical/Structural
Storage Devices	Components, Electrical/Electronic
Strength and Weight Factors	Design Considerations
Switches	Components, Electrical/Electronic
Systems, Testing	Test and Measurement
T	
Temperature Limits	Test and Measurement
Terminals	Components, Electrical/Electronic (*Wiring Devices*)
Test Equipment	Test and Measurement
Thermal and Acoustical Insulation	Materials, Mechanical/Structural
Thermal Design Factors	Design Considerations
Thermal Dissipation	Heat Flow
Thermistors	Components, Electrical/Electronic (*Semiconductor Devices*)
Thermostats	Components, Electrical/Electronic (*Transducers*)
Transducers	Components, Electrical/Electronic
Transformers	Components, Electrical/Electronic (*Magnetic Components*)
Transistors	Components, Electrical/Electronic (*Semiconductor Devices*)
U	
Unitized Construction	Production and Assembly Techniques
V	
Varnishes, Insulating	Materials, Electrical/Electronic (*Electrical Insulation and Dielectrics*)
W	
Waveguides	Components, Electrical/Electronic (*Microwave Components*)
Wire and Cable	Components, Electrical/Electronic
Wire Enamel and Insulation	Materials, Electrical/Electronic (*Electrical Insulation and Dielectrics*)
Wiring Devices	Components, Electrical/Electronic
Wiring Harness	Components, Electrical/Electronic (*Wire and Cable*)

Editorial Subject Classification

Science & Engineering
- Chemistry of Materials
- Dielectrics
- Mathematics
- Network Analysis
- Network Synthesis
- Physics
- Systems

Components, Electrical/Electronic
- Batteries
- Capacitors
- Contact Devices
- Electron Tubes
- Embedded Circuits
- Magnetic Amplifiers
- Magnetic Components
- Meters, Panel-type
- Microcircuit Assemblies
- Microwave Components
- Motors (classified separately)
- Potentiometers and Resistors
- Power Sources
- Power Supplies
- Printed Circuits
- Protective Devices
- Semiconductor Devices
- Shielding Devices
- Storage Devices
- Switches
- Thermoelectric Devices
- Transducers
- Wire and Cable
- Wiring Devices

Components, Mechanical/Structural
- Bearings
- Drive Elements
- Fasteners
- Gears
- Housings
- Seals and Gaskets
- Shock and Vibration Isolators
- Springs
- Thermal

Computing Machines (see also: Systems, Digital)
- Applications

Design Considerations
- Cost Factors
- Electrical Noise
- Environmental Effects
- Human Factors
- Maintainability
- Materials Selection Factors
- Miniaturization
- Radio Noise and Interference
- Reliability
- Strength and Weight Factors
- Thermal Design Factors

Heat Flow

Instruments and Test Equipment
- Design (see also: *Test and Measurement*)

Materials, Electrical/Electronic
- Conductor Materials
- Contact Materials
- Electrical Insulation and Dielectrics
- Magnetic Materials
- Metals
- Semiconductor Materials

Materials, Mechanical/Structural
- Adhesives
- Composite Materials
- Metals
- Nonmetallic Materials
- Protective Coatings
- Thermal and Acoustical Insulation

Motors
- Fractional-Horsepower
- Instrument
- Integral-Horsepower
- Special

Product Design Case History

Production and Assembly Techniques
- Automatic Assembly
- Embedded Circuits and Components
- Hermetic Sealing
- Miscellaneous
- Packaging
- Printed Wiring
- Soldering and Solderless Techniques
- Unitized Construction

Specifications and Standards

Systems
- Amplifier Circuits
- Analysis
- Circuit Design
- Communication
- Control
- Control Case Histories
- Digital
- Drive
- General
- Mechanical
- Modular Subsystems
- Power
- Recording

Test and Measurement
- Components
- Environmental
- General
- Materials
- Principles and Techniques
- Production
- Systems

New Alphabetical Subject Cross Index*

Subject	*Classification*
A	
Acoustical Insulation	Materials, Mechanical and Structural
Adhesives	Materials, Mechanical and Structural
B	
Batteries	Components, Electrical/Electronic Power Sources
Bearings	Components, Mechanical
Brushes	Components, Electrical/Electronic, Contact Devices
C	
Capacitors	Components Electrical/Electronic, *Other*
Casting Resins	Materials, Electrical, Insulating
Ceramic Dielectrics	Materials, Electrical, Insulating
Ceramic-Metals	Materials, Composite
Cements	Materials, Mechanical and Structural
Chemistry	Science and Engineering: Materials, Fundamental Structure
Circuit Analysis	Science and Engineering, Network Theory
Clad Metals	Materials, Mechanical and Structural
Coaxial Cable	Components, Electrical/Electronic, Wire and Cable
Commutators	Components, Electrical/Electronic, Contact Devices
Component Failure	Design Considerations, Reliability
Component Testing	Test and Measurement
Composite Materials	Materials, Composite
Computer Design	Systems, Computing
Computer Use	Design Engineering Techniques
Connectors	Components, Electrical/Electronic, Wiring Devices
Control Instruments	Systems, Control
Cooling	Design Considerations, Thermal
Corona Effects	Test and Measurement, Materials; Materials, Electrical Insulating and Dielectric
Cryogenic Materials	Materials, Superconductive; Design Considerations, Environmental
Cryogenics	Science and Engineering, Materials: Fundamental Phenomena
D	
Delay Lines	Components, Electrical/Electronic, Microwave
Dielectrics	Science and Engineering, Materials, Fundamental Phenomena; Physics
Diodes	Components, Electrical/Electronic, Semiconductor
Drives	Components, Mechanical; Systems
E	
Elastomers	Materials, Mechanical and Structural; Materials, Electrical Insulating and Dielectric
Electron Tubes	Components, Electrical/Electronic
Embedded Circuits	Circuit Design, Integrated; Components Electrical/Electronic
Engineering Psychology	Science and Engineering, Life Science; Design Considerations, Human Factors
Environmental Factors	Design Considerations, Environmentals; Test and Measurement, Environmental
F	
Failure	Design Considerations, Reliability
Fasteners	Components Mechanical, *Other*
Ferrites	Materials, Magnetic
Field Theory	Science and Engineering, Physics and Communications Theory
Fluid Mechanics	Science and Engineering, Physics; Systems, Control, Drive, *Other*; Components, Mechanical, Hydraulic/Pneumatic
G	
Gaseous Dielectrics	Materials, Electrical Insulating
Gears	Components, Mechanical
H	
Heat	Science and Engineering, Physics; Design Considerations, Thermal Design Factors
Human Factors	Design Considerations; Science and Engineering, Life Sciences
Humidity Effects	Design Considerations, Environmental
Hydraulics	Science and Engineering, Physics; Systems, Control, Drive, *Other*; Components, Mechanical, Hydraulic/Pneumatic
I	
Inductors	Components, Electrical/Electronic, Inductive
Instrument Application	Test and Measurement
Instrument Design	Test and Measurement
Insulation Testing	Test and Measurement, Materials
International Standards	Test and Measurement, Specifications and Standards
L	
Liquid Dielectrics	Materials, Electrical Insulating
Lubricants	Materials, Mechanical and Structural
M	
Magnet Wire	Components Electrical/Electronic, Wire and Cable; Materials Electrical Insulating and Dielectric
Magnetic Amplifiers	Circuit Design, Amplifier; Systems, Control; Components Electrical/Electronic, Inductive
Magnetism	Science and Engineering, Physics; Materials, Fundamental Phenomena; Components, Electrical/Electronic, Inductive Devices
Maintainability	Design Considerations
Materials Testing	Test and Measurement
Memory Devices	Components Electrical/Electronic, *Other*
Metallurgy	Science and Engineering, Materials, Fundamental Structure
Metals	Materials
Microcircuit Assemblies	Components, Electrical/Electronic; Circuit Design, Integrated
Miniaturization	Design Considerations, Space and Weight
Modular Construction	Circuit Design, Modular; Design Considerations, Space and Weight
Modulation	Science and Engineering, Communications Theory
N	
Nomographs	Design Engineering Techniques, Graphical
Nuclear Radiation	Design Considerations, Environmental
O	
Optics	Science and Engineering, Physics; Components, Electrical/Electronic, Optical and Infrared
P	
Plastics and Polymers	Materials, Electrical; Materials, Mechanical and Structural
Pneumatics	Science and Engineering, Physics; Systems, Control, Drive, *Other*; Components, Mechanical, Hydraulic/Pneumatic
Potentiometers	Components Electrical/Electronic, Resistive

*Note: To be used beginning with the January 1964 issue.

Subject	*Classification*
Power Generators	Systems, Power; Components Electrical/Electronic, Power
Printed Circuits	Components, Electrical/Electronic
Printed Circuit Boards	Materials, Electrical Insulating and Dielectric
Production Test	Test and Measurement, Production
Q	
Quality Control	Test and Measurement, Production
R	
Radar	Science and Engineering, Communications Theory; Systems, Communication, Navigation, Guidance, Surveillance
Radio Interference	Design Considerations, Noise and Interference
Recording Instruments	Test and Measurement, Instrument and Test Equipment; Systems, Recording
Rectifiers	Components, Electrical/Electronic
Relays	Components, Electrical/Electronic, Contact Devices
Reliability	Design Considerations
Resistance Wire	Materials, Conductive and Resistive
Resistors	Components Electrical/Electronic, Resistive
Resolvers	Components Electrical/Electronic, Transducers
S	
Sealants	Materials, Mechanical and Structural
Semiconductor Devices	Components, Electrical/Electronic
Sensing Elements	Components Electrical/Electronic, Transducers
Servos	Systems, Control
Shielding	Design Considerations, Noise and Interference; Materials, Magnetic
Shock and Vibration	Design Considerations, Environmental; Test and Measurement, Environmental
Slip Rings	Components, Electrical/Electronic, Contact Devices
Sockets	Components Electrical/Electronic, Wiring Devices
Sound	Science and Engineering, Physics
Specifications	Test and Measurement
Standards	Test and Measurement
Statistics	Design Engineering Techniques, Applied Mathematics
Storage Devices	Components, Electrical/Electronic, *Other*
Switches	Components, Electrical/Electronic, Contact Devices
Synchros	Components, Electrical/Electronic, Transducers
Systems, Testing	Test and Measurement
T	
Tachometer Generators	Components Electrical/Electronic, Transducers
Temperature	Science and Engineering, Physics; Design Considerations, Thermal; Test and Measurement
Terminals	Components, Electrical/Electronic, Wiring Devices
Test Equipment	Test and Measurement
Thermal Design	Design Considerations, Thermal
Thermal Dissipation	Science and Engineering, Physics; Design Considerations, Thermal
Thermal Insulation	Materials, Mechanical and Structural
Thermistors	Components, Electrical/Electronic, Semiconductor
Thermodynamics	Science and Engineering, Physics
Thermoelectric Effects	Science and Engineering, Physics; Components, Electrical/Electronic, Thermoelectric Devices
Thermoelectric Materials	Materials, Semiconductive
Thermostats	Components Electrical/Electronic, Transducers
Transducers	Components, Electrical/Electronic
Transformers	Components, Electrical/Electronic, Inductive
Transistors	Components, Electrical/Electronic, Semiconductive
V	
Vibration	Design Considerations, Environmental, Mechanical Design Factors; Test and Measurement, Environmental
W	
Waveguides	Components, Electrical/Electronic, Microwave
Wire and Cable	Components, Electrical/Electronic
Wire Insulation	Materials, Electrical Insulation
Wiring Devices	Components, Electrical/Electronic

New Editorial Subject Classification*

Basic Science & Engineering
- Communications Theory
- Life Sciences (bionics; engineering psychology)
- Materials: Fundamental Phenomena
- Materials: Fundamental Structure
- Mathematics
- Network Theory
- Physics
- Systems Theory
- *Other*

Circuit Design (see *Systems* below)
- Amplifier
- Digital; Logic
- Filter
- Integrated
- Modular
- Oscillator
- Semiconductor
- *Other*

Components, Electrical/Electronic
- Contact Devices (switches; relays)
- Electron Tubes
- Inductive Components (transformers; inductors)
- Magnetic Devices
- Microcircuit Assemblies
- Microwave Components
- Motors, Instrument
- Motors, Power
- Optical and Infrared Devices
- Photoelectric Devices
- Power Sources, Supplies
- Printed and Embedded Circuits
- Resistive Components (resistors; potentiometers)
- Semiconductor Devices
- Thermoelectric Devices
- Transducers
- Wire and Cable
- Wiring Devices (connectors; terminals)
- *Other*

Components, Mechanical
- Bearings
- Drive Elements (brakes; clutches)
- Gears (trains; reducers)
- Hydraulic/Pneumatic
- *Other*

Design Considerations
- Cost Factors
- Environmental Factors
- Human Factors
- Maintainability
- Mechanical Design Aspects; Packaging
- Noise and Interference
- Reliability
- Space and Weight Factors
- Thermal Design Factors
- *Other*

Design Engineering Techniques
- Analog and Simulation Methods
- Applied Mathematics
- Computer Applications
- Engineering Literature Retrieval
- Graphical Methods
- *Other*

Materials
- Composite
- Conductive and Resistive
- Electrical Insulating and Dielectric
- Magnetic
- Mechanical and Structural
- Semiconductive
- Superconductive
- *Other*

Systems (see *Circuit Design* above)
- Communication
- Computing; Data; Recording
- Control
- Display
- Drive; Propulsion
- Navigation; Guidance; Surveillance
- Power, Electrical
- Test and Measurement Systems
- *Other*

Test and Measurement
- Environmental Testing
- Instruments and Test Equipment
- Production Testing
- Specifications and Standards
- Testing of Components
- Testing of Materials
- Testing of Systems
- *Other*

* Note: To be used beginning with the January 1964 issue.